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FIELD EXPERIMENTS WITH ANTI-TORTRIX FLUIDS.

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Peradeniya,

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DEPARTMENT OF AGRICULTURE, CEYLON.

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FIELD EXPERIMENTS WITH ANTI-TORTRIX FLUIDS.

IN order to appreciate fully the necessity of possessing an anti-tortrix fluid which may be sprayed upon the tea bushes at any time, irrespective of plucking, and without injuring the bush or depreciating the made tea, it is essential to outline the proposed scheme of control.

As the south-west monsoon is responsible for the general dissemination of Tea Tortrix, and as every local breeze tends to distribute the moth over estates, those areas of tea unprotected from wind are liable to attack at any time. The Investigator has endeavoured to point out the absolute necessity of each estate possessing a system of wind belts, otherwise known as flight breaks (see Tortrix Flight Breaks, Bulletin No. 45). The objects of the flight breaks are: (1) To arrest the moth in its forced flight, and so check it spreading over the country; and (2) to afford it breeding grounds other than the estate tea. The moth will be held up by the flight breaks, it will establish itself in them, and the tea will be free from the insect. When the flight breaks become overcrowded and the insect shows signs of migrating to the tea, it can be cheaply and conveniently killed in the flight breaks by the application of arsenical washes. Should the insect attack the tea, the anti-tortrix fluid becomes the weapon with which to kill the pest on the tea, and making the bushes distasteful to it, those insects which do not devour the treated tea are forced to return to the flight breaks, where ultimately they will be dealt with.

The whole crux of the matter is arsenical washes must not be used on such a marketable product as tea, but the Investigation must possess a solution which may be sprayed on to tea and which will kill the insect, yet have no deleterious effect to either the flushing capacity of the bush or the made tea.

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The points on which this anti-tortrix fluid must be satisfactory and fully tested are very severe and numerous; they are as follows :—

(1) The wash must be cheap.
(2) The ingredients must be easily procurable.
(3) The wash must be easily manufactured under estate conditions.
(4) It must keep in good condition for long periods.
(5) It must be easy of application.
(6) It must be perfectly safe in the hands of the cooly.
(7) It must in no way injure the bush.
(8) It must kill the insect.
(9) It must have no deleterious effect on the made tea.
(10) It must be such that it can be applied to the tea at any time irrespective of plucking.

It would be difficult to find a more severe test for any insecticide. The Investigation now places its report before the public. This shows that after six months of continual testing under absolute estate conditions, the anti-tortrix fluid used passes every test.

The Site of the Area under Experimentation.

Through the keenness and enthusiasm of Mr. R. B. Harvey, of Maskeliya, the Colombo Commercial Company kindly placed an acre of tea at the absolute disposal of the Investigation for experimental purposes. When one considers that an acre of full growing tea is put out of commission as a profit yielding concern for over six months by a single firm, it points to a keen desire on the part of the planting community to get control of the Tortrix difficulty. The Investigation has great satisfaction in stating that, owing to the success of the experiments, all the tea taken from the acre, with the exception of 73 lb. used as samples, was returned to the firm, which has eliminated any likelihood of loss on the firm's part.

The area selected was on Emelina estate, Maskeliya, and stood at an elevation of 4,400 feet. The site was carefully chosen, in order to present every difficulty ever likely to be met with in spraying under estate conditions. These difficulties are :—

(1) Large full-leafed bushes affording perfect harbourage for Tortrix, and from which it is the most difficult to exterminate.
2) Such bushes demand the maximum of spray and are the most difficult to spray.

(3) High bluff with full exposure to the south-west monsoon.
(4) Steep land high up on estate far from a source of water.

In selecting a field with large (old) full-leafed bushes, the Investigation was aware that the maximum amount of spray would be needed, and that naturally the costs of spraying would be high; also the difficulty of thoroughly wetting every leaf of every bush would make the actual operation of spraying one of the most severe.

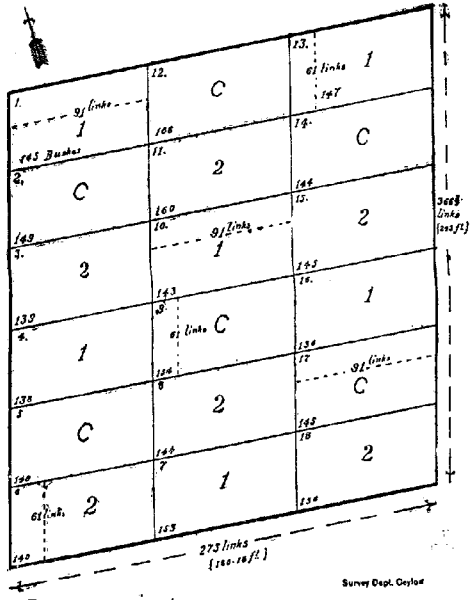
The costs to be quoted should represent the highest ever necessary in old fully-leafed tea, also the amount of fluid used should be the greatest ever necessary. Though the Investigation selected tea coming into pruning, it should never be necessary to spray old bushes; for, should such tea be attacked, it would be wiser and more economical to prune it before its time, burn or bury the prunings, and thus kill the insect. It is on young tea just out from pruning that Tortrix does vital damage, and comparing the density of foliage of young tea with old bushes and the amount of fluid the Investigation has successfully used on old tea, it is easily understood that the costs may be reduced by a third of their amount to represent the cost for practical spraying.

Should it be decided not to spray old tea possessing Tortrix, that tea should be pruned, and the prunings burnt or buried, because the insect in this old tea will be a continual menace to the younger crop.

The high bluff fully exposed to the south-west monsoon and far up the estate on steep land was purposely selected as presenting the most difficult problem to be faced in spraying, namely, water transport. Of all details likely to condemn a scheme of spraying, water transport is that detail. The area chosen for experimentation presents the problem in all its seriousness. This point is fully discussed under Water Transport.

The Topography of the Maskeliya Valley.

The valley consists of a series of more or less parallel ranges of hills lying between two mountain ranges, the northern mountain range runs in a north-westerly direction, while the southern runs north-west by west. These mountains thus form a huge funnel, the mouth of which faces towards the west, and presents a perfect conduit for the full force of the south-west monsoon. The experimental area lies on the northern range, a little above the parallel hill ranges, with full exposure to the south-west monsoon.



Plan of Experimental Area

Details of the Experimental Area.

The experimental area, being one acre in extent, was divided into eighteen equal plots, six of which were devoted solely to No. 1 wash, six to No. 2 wash, while the remaining six were control plots. All plots were separated from one another by a double line of stout coir rope, which eliminated any possibility of the pluckers taking flush from neighbouring plots. The pluckers were under constant supervision. Owing to this constant supervision and the double line of ropes, there was no possibility of the flushes of various plots being mixed during plucking. This point bears great importance to the whole series of experiments.

On the plan of the experimental area those plots marked 1 have been treated with No. 1 wash, plots marked 2 with No. 2 wash, and those marked C are control or untreated

plots. The controls constitute plots for comparison with the treated plots. The figures in the top left hand corners are the numbers of the plots, and those in the lower left hand corners the number of bushes to the plot.

The area of each plot is equal, but the number of bushes in each varied slightly. The controls possess 38 bushes more than No. 1 plots and 16 bushes more than No. 2 plots. No. 1 plots possess 862 bushes, No. 2 plots possess 884 bushes, control plots possess 900 bushes, making a total of 2,646 bushes per acre, and an average of 147 bushes per plot.

The controls were so arranged that the best comparisons of yields were possible, and incidentally, in the event of the insect establishing itself in the controls, there was every possibility of infection spreading to the treated plots.

When the experiments were started, the whole area had a very slight attack of Tortrix, thus were the conditions equal.

Four pluckers were sufficient to pluck the acre in a day, and the principle adopted was that all controls were plucked first, then the No. 1, and lastly the No. 2 plots ; this prevented any likelihood of the dry solution being carried on the hands of the pluckers to the flush of the controls. The leaf from each plot was accurately weighed directly the plot was finished, the weight of each plucker's basket being taken periodically during plucking and the amount deducted from the total weight of basket and leaf. The leaf from all No. 1 plots was put into a special basket, the leaf from No. 2 and the controls also had their respective baskets, and all through the six months of experimentation those baskets were never changed, obviating any possibility of the leaf from different series being mixed.

Details of the Manufacture of the Leaf.

In the factory a sufficient portion of the withering tats was put at the disposal of the Investigation ; the portion was divided into three sections, and these sections were separated from one another by three feet of alleyway. Again, the possibility of the leaf being mixed was non-existent. The leaf from the No. 1, No. 2, and control plots were separately withered.

The quantity of withered leaf from the three series was not sufficient for a large roller, it, therefore, had to be rolled by hand. Two rolling tables were constructed, the one solely for the leaf from the control plots, and the other for the leaf from No. 1 and No. 2 plots. The leaf of the controls was

rolled first, whilst the hands of the rolling coolies were clean, then No. 1 was rolled on the table allotted for it, and lastly No. 2 rolled on the same table as the No. 1 leaf. There was, therefore, no possibility of the treated leaf mixing with that of the controls.

The reason why No. 2 could be rolled on the same table as No. 1 was because No. 1 and No. 2 anti-tortrix washes contain exactly the same amounts of Lead Chromate, but as No. 2 possessed yet another ingredient, it was rolled last. After rolling the two tables were thoroughly scraped, washed with water, and placed aside to drain and dry.

The same principle was adopted in firing the leaf, controls first, No. 1 second, and No. 2 last, each tea as it was made being placed in its special box to await the reports of the experts before handing the tea back to the estate.

This matter of the preparation of the samples has been treated at length, but it is necessary to emphasize that there was no possibility of the leaf being mixed or the tea being contaminated in any way.

Expert Consideration of Samples.

Fifteen of the senior tea agents of Colombo generously undertook to test and report upon samples of every break. These samples were despatched regularly in the recognized sample tins, not in lead packets. The experts were quite unaware as to which samples were treated, the samples being marked 1, 2, and 3, or A, B, and C. After all the reports of a break had been received, each firm was given detailed information as to the preparation of the samples they had reported upon.

These reports were of vital importance to the experiments, for it allowed the Investigation to watch closely any trace of taint in the tea and to gauge the maximum amount of Chromate that could be used without tainting the tea, and also how close to plucking spraying could be brought.

The Experiments.

Plucking.—The first plucking was taken on January 20, 1919, and continued at regular intervals of twelve days until June 14. Estate conditions were in no way interfered with; it was the general rule to pluck every twelve days during that season, and the experimental area was plucked at such intervals.

The following table shows the yields for the 13 pluckings:—

Yields of Green Leaf from the Experimental Acre in lb.

Pluckings.	Date.	Amount for all No. 1 Plots. lb.	Amount for all No. 2 Plots. lb.	Amount for all Control Plots. lb.	Total. lb.
First	Jan. 20	16	18½	16½	51
Second	Feb. 1	33½	31½	28	93*
Third	Feb. 13	27½	29	28½	85*
Fourth	Feb. 25	39	39	37	115*
Fifth	Mar. 9	21½	23	23	67½†
Sixth	Mar. 22	19	22	15½	56½†
Seventh	April 3	14	17½	13	44½‡
Eighth	April 15	17½	22½	25	65‡
Ninth	April 27	30	34½	31	95½‡
Tenth	May 9	28½	29½	26½	84½§
Eleventh	May 21	26½	35½	23	85§
Twelfth	June 2	27½	33	21½	82‖
Thirteenth	June 14	26½	33	27	86½‖
	Total	327	368½	315½	1,011

* Total for February 293 lb.
† Total for March 124 lb.
‡ Total for April 205 lb.
§ Total for May 169½ lb.
‖ Total for half June 168½ lb.

For a comparison of yields of previous years on the same *acre*, the following figures are useful:—

In 1915 the yield of green leaf was	971 lb.	per acre per annum.
In 1916	do.	do.
In 1917	do.	do.
In 1918	do.	do.

For comparison of the monthly yields of green leaf of the experimental acre for the last three years, the figures are:—

Period of Experimentation.	1917.	1918.	1919.
January	76	75	51*
February	52	74	293
March	84	110	124
April	93	74	205
May	102	127	169½
June	62	122	168½
Total	469	582	1,011

* One plucking only.

The acre was pruned in July, 1917; in May and June of that year it was bearing only 102 lb. and 62 lb., as against 169½ and 168½ lb. for the same months this year. The field was again pruned in July this year.

These figures are most satisfactory, and tend to show that the treatment the acre has received while under experimentation has greatly augmented the yield. These figures may be put aside having been useful for comparison only. To prove mathematically whether the yield has been benefited by the treatment, the yields of the experiments only will be taken into consideration.

The control plots are untreated, and represent tea at estate conditions. It has been previously stated that the control plots possess 38 bushes more than No. 1 plots and 16 bushes more than No. 2 plots. This fact should show a likelihood of the controls yielding more than the treated plots.

A comparison of the results in the table of pluckings above shows that plots treated with No. 2 wash have given a greater yield than either the controls or the plots treated with No. 1 wash, and that the yield of the No. 1 plots is possibly greater than the controls.

By applying the "method of least squares" to the experimental data a true interpretation of the results will be arrived at.

In accurately interpreting experimental results, it is necessary to allow for "natural" errors, *i.e.*, errors that cannot be eleminated, and which are due to operation, differences in properties of soil, conditions, and situations, &c. "By the application of certain mathematical methods, one of which is 'the method of least squares,' to the results of experiments, a single numerical expression, usually referred to as the 'probable error,' may be calculated for all errors. The probable error is a measure of the reliability of a result, and is such that the chances are even, that the difference between any single result and the average of the results will be greater or less than the amount of the probable error."*

The formula for ascertaining the probable error of any one result from the mean of several by the "method of least squares" is: Probable error $= \cdot 67\sqrt{\frac{\Sigma d^2}{n-1}}$, where d equals the difference between a result and the average of all results, where Σd^2 equals the sum of the squares of the differences, and where n equals the number of results.

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* Probable error in field experimentation with *Hevea*, G. O. F. Bishop, J. Grantham, and M. D. Knapp.

Plots: / Pluckings.	Yields at each Plucking in lb.			d Difference between the Average Yield and the Yield of each Plucking.			d^2 Square of the differences in Yield of Plots.		
	No. 1.	No. 2.	Controls.	No. 1.	No. 2.	Controls.	No. 1.	No. 2.	Controls.
First	16·0	18·5	16·5	9·15	9·84	7·76	83·79	96·94	60·35
Second	33·5	31·5	28·0	8·34	3·15	3·73	69·65	9·94	13·92
Third	27·5	29·0	28·5	2·34	·65	4·23	5·50	·42	17·90
Fourth	39·0	39·0	37·0	13·84	10·65	12·73	191·71	113·50	162·07
Fifth	21·5	23·0	23·0	3·65	5·34	1·26	13·35	28·59	1·61
Sixth	19·0	22·0	15·5	6·15	6·34	8·76	37·87	40·27	76·89
Seventh	14·0	17·5	13·0	11·15	10·84	11·26	124·41	117·63	126·99
Eighth	17·5	22·5	25·0	7·65	5·84	·73	58·58	34·17	·53
Ninth	30·0	34·5	31·0	4·84	6·15	6·73	23·48	37·87	45·30
Tenth	28·5	29·5	26·5	3·34	1·15	2·23	11·19	1·33	4·97
Eleventh	26·5	35·5	23·0	1·34	7·15	1·26	1·81	51·17	1·61
Twelfth	27·5	33·0	21·5	2·34	4·65	2·76	5·50	21·65	7·66
Thirteenth	26·5	33·0	27·0	1·34	4·65	2·73	1·81	21·65	7·45
Total Yield	327·0	368·5	315·5				628·65	575·11	527·35
Average Yield	25·15	28·34	24·26						

Probable error of No. 1 $= \cdot 67\sqrt{\frac{\Sigma d^2}{n-1}}$

$= 67\sqrt{\frac{628 \cdot 65}{12}}$

$= 1 \cdot 399$
$= 1 \cdot 4$ approximately

Probable error of No. 2 $= \cdot 67\sqrt{\frac{\Sigma d^2}{n-1}}$

$= \cdot 67\sqrt{\frac{575 \cdot 11}{12}}$

$= 1 \cdot 33$
$= 1 \cdot 3$ approximately

Probable error of controls $= \cdot 67\sqrt{\frac{\Sigma d^2}{n-1}}$

$= \cdot 67\sqrt{\frac{527 \cdot 35}{12}}$

$= 1 \cdot 28$
$= 1 \cdot 3$ approximately

Average yield of No. 1 $= 25 \cdot 15$

$25 \cdot 15 \pm 1 \cdot 4 < \begin{matrix} 23 \cdot 75 \\ 26 \cdot 55 \end{matrix}$ No. 1 is equal to, or more than, the controls.

Average yield of No. 2 $= 28 \cdot 34$

$28 \cdot 34 \pm 1 \cdot 3 < \begin{matrix} 27 \cdot 04 \\ 29 \cdot 64 \end{matrix}$ No. 2 > controls : > No. 1.

Average yield of controls $= 24 \cdot 26$

$24 \cdot 26 \pm 1 \cdot 3 < \begin{matrix} 22 \cdot 96 \\ 25 \cdot 56 \end{matrix}$ Controls are equal to, or less than, No. 1 and less than No. 2.

The above comparisons show that tea bushes treated with No. 2 wash have benefited over those treated with No. 1 wash, and also the controls; that bushes treated with No. 1 wash have benefited over the untreated bushes (controls), but to a less degree than those treated with No. 2 wash.

It has been mathematically proved that the washes have no deleterious effect upon the flushing capacity of the bush. Results further show that the washes have a beneficial effect upon the flushing capacity of the bush.

Several planters who visited and looked into the experiments voiced the possibility that this undoubted benefit might be due to the fact the treated plots received a certain amount of liquid (spray fluid) during the drought which the controls did not receive. The actual period of the drought was 41 consecutive days with but ·66 inch of rain, from the middle of February to the end of March; during that time four sprayings had been made, at each spraying 109 gallons of liquid were sprayed over the treated plots, making the total of 436 gallons, this is equal to ·042 inch of rainfall, which is not sufficient to have any effect whatever on the bushes.

When it is understood that during the tests the Tortrix that was present in the acre at the commencement of the experiments was killed by the spray in the treated plots, but developed, though to a slight extent, in the controls, the reason of the benefit is obvious. Insects could not, and did not, exist in the treated plots, but were present in a mild form in the controls.

The controls being untreated were liable to attack, but the insect could not exist in the treated plots, though it constantly endeavoured to establish itself in them. Not only Tortrix, but also "Nettle grubs" *Thosea* spp., *Gracilaria theivora*, *Oscinis theæ*, *Ceylonia theæcola*, and *Chionaspis theæ* were taken on several occasions from the controls, but were absent from the treated plots, especially was this evident in the No. 2 plots.

That the treatment in no way injures the bush, but tends to improve its condition by making the tea uninhabitable to insects is proved. The washes and their effect upon the marketable product are the next points for consideration.

The Washes.

In selecting an insecticide for use on products for human consumption great care must be exercised. Speaking generally, there are two classes of insecticides: Stomach washes and Contact washes. The former are used against leaf-eating insects, such as caterpillars, beetles, grasshoppers, and other biting insects; the latter against insects which suck the sap of plants, such as bugs, scale insects, and the like.

Tortrix being a caterpillar, and one which protects itself from contact by curling the flush around itself, is an insect against which contact washes will have no effect; it, therefore, becomes necessary to use some form of stomach wash, which when sprayed on the leaves and devoured by the caterpillar

will effect its death by poisoning. As previously stated, a poison must not be used on tea, but some wash which will kill the insect and which will have no poisonous effect on the marketable product must be found.

Lead Chromate was selected as meeting every requirement; it possesses a moderate degree of poisonous effect on the caterpillar, is not injurious to the plant, it is insoluble in water, and is not decomposed by atmospheric influences.

It is the perfect substitute for stomach washes, and may be used in very strong solutions without injurious effect.

Lead Chromate may be bought in the form of dry powder or in paste, or it may be manufactured by the user by mixing 1 ounce Potassium Bichromate with 2 ounces of Lead Acetate, when 2 ounces of Lead Chromate will be precipitated as a flocculent yellow mass :—

Lead Acetate		Potassium Bichromate		Water
$2\ Pb\ (C_2H_3O_2)_2$	+	$K_2Cr_2O_7$	+	H_2O
$= 2\ Pb\ CrO_4$	+	$2\ KC_2H_3O_2$	+	$2\ HC_2H_3O_2$
Lead Chromate		Potassium Acetate		Acetic Acid.

The Lead Chromate used by the Investigation was in the form of powder, and was bought from Messrs. Waldie & Co., Ltd., Konnagar, Calcutta, in 20-lb. lots.

20 lb. Lead Chromate cost the Investigation as follows:—

	Rs.	c.
20 lb. Lead Chromate	50	0
Packing and transport charges ..	7	50
Total ..	57	50

equals approximately 17¾ cents per ounce of Lead Chromate.

Cost of the Washes.

No. 1 Wash was purely Lead Chromate, and cost 17¾ cents per ounce. The Chromate was used at the rate of 3 ounces per plot, six plots of the experimental area being devoted to No. 1 wash, the cost was:—

	Rs.	c.
18 ounces Lead Chromate, at 17¾ cents per ounce ..	3	19½
Two coolies transporting water and spraying for half a day, at 38 cents per day (check roll average) ..	0	38
Actual cost of spraying with No. 1 wash ..	3	57½

All the No. 1 plots constituted but one-third of an acre, therefore the cost of spraying one acre of old bushes with No. 1 wash equals Rs. 10·72½.

No. 2 Wash differs materially from No. 1. The formula is :—

1 ounce Lead Chromate
¼ pint Rosin Compound
3 gallons water
} per 3 gallons Knapsack Sprayer.

Rosin compound is composed of 2 lb. of Powdered Rosin, 1 lb. of Sodium Carbonate (common washing soda), and 1 gallon of water.

Preparation.—Boil the soda with 1 gallon of water, add the rosin to the boiling soda water and continue boiling. Each time the solution boils up, which it will do persistently, add a small cupful of cold water and allow to boil up again. Keep adding small quantities of cold water until the solution becomes clear like thin coffee. When the required density is reached, the quantity of solution will amount to about 3 gallons.

The cost of 3 gallons of Rosin Compound is :—

	Rs.	c.
2 lb. Rosin (as procurable from Messrs. Cargills, Ltd.), at Re. 1 per lb.	2	0
1 lb. Sodium Carbonate (from Messrs. Cargills, Ltd.), at Re. 1 per lb.	1	0
⅛ yard of firewood, at Re. 1 per yard	0	12½
Attendant cooly half day, at 38 cents per day ..	0	19
Three gallons concentrated wash ..	3	31½

This equals Re. 1·10$\frac{1}{16}$ per gallon, or 13$\frac{3}{4}\frac{7}{8}$ cents per pint.

Nine gallons of solution were sprayed on each plot, *i.e.*, three fills of a 3-gallon Knapsack Sprayer; there are six plots devoted to No. 2 wash, therefore the cost of No. 2 wash is :—

	Rs.	c.
18 ounces Lead Chromate, at 17$\frac{3}{4}$ cents per oz. ..	3	19½
($\frac{3}{4}$ pint Rosin Compound per plot: 6 plots, at $\frac{3}{4}$ pint = 4½ pints)		
4½ pints Rosin Compound, at 13$\frac{7}{8}$ cents per pint ..	0	16$\frac{3}{4}$
2 coolies transporting water and spraying for half a day, at 38 cents per day (check roll average) ..	0	38
Actual cost of spraying with No. 2 wash ..	4	19$\frac{1}{4}$

All the No. 2 plots constitute but one-third of an acre, therefore the cost of spraying one acre of old bushes with No. 2 wash = Rs. 12·58$\frac{1}{3}\frac{3}{3}$. To spray an acre with No. 1 wash costs Rs. 10·72½, and with No. 2 wash Rs. 12·58. These prices appear excessive, but they include labour, water transport, and manufacture; at the present moment materials alone are costing, in the case of No. 1 Rs. 9·58½ per acre, and Rs. 11·44½ for No. 2. Materials are expensive, but they will

not always be so ; were larger quantities ordered even now, costs could be reduced by a third ; also it must not be forgotten the experiments represent every difficulty likely to be met with in spraying, and the maximum amount of solution was used, and, again, as pointed out on page 3, it should never be necessary to spray such old tea. For all practical purposes spraying should cost no more than Rs. 7·14 per acre for No. 1 and Rs. 8·38 for No. 2.

To be able to kill the insect on 2,646 old full-leafed bushes for the sum of Rs. 8·38, and have immunity from leaf-eating insects for a period of two months after spraying, allows for the assumption that the benefit derived by the wash and the term of immunity it gives reduces the cost to a practical basis.

Preparation of the Washes.

Every matter connected with the spraying was carried out under ordinary estate conditions. The Chromate for No. 1 wash was weighed into one ounce lots and placed in old envelopes. The wash was made on the field. As stated, the Knapsack spraying machine had a capacity of 3 gallons of liquid, and 1 ounce of Chromate was used to a fill. The Chromate powder was mixed with water to a thick paste in a tin, then poured into a bucket containing 2 gallons of water, this was then poured into the Knapsack container through a sieve funnel, and water added to fill the machine up to the 3-gallon mark.

Exactly the same method was used with No. 2 wash, except that a quarter of a pint of the Rosin Compound was poured into the bucket containing the Chromate solution, mixed up with it, and poured into the Knapsack container.

The preparation of the Rosin Compound was not so simple ; it has been explained on page 13. The compound was made in a 6-gallon drum (see plate facing page 19) in the bungalow yard ; the drum was placed on two iron bars supported on bricks sufficiently high from the ground to allow for fire space. When the wash is made, it is allowed to cool, and is then stored in the drum in which it was made, just a sufficient quantity for the spraying being carried to the field at a time. The Rosin Compound can be kept for long periods without depreciating. Both washes are easily manufactured under estate conditions.

The Difference between the Washes.

In the selection of a wash the "surface tension" of the liquid must be considered. The point is made clear by illustration. When water is thrown on to a leaf, the whole surface is not covered with a film, but the water forms into globules

here and there, leaving the rest of the leaf dry. For perfect spraying some substance must be mixed with the solution which will cause it to have a low " surface tension " and form a complete film over the leaf. The value of this is seen in spraying for Tortrix. No. 1 wash is pure Chromate and water, and when sprayed on tea the leaves are spotted instead of the whole surface being covered. When one remembers that during the first eight days of larval life the minute caterpillars eat but small patches of the leaf, it is obvious that these little creatures could feed on leaves sprayed with No. 1 wash by devouring between the spots of Chromate.

No. 2 wash possesses a very low surface tension ; the Rosin Compound is responsible for this ; the soda forms the complete film, and the Rosin causes the wash to glue itself to the leaf.

A valuable, but unexpected, property of No. 2 wash is that the soda of the Rosin Compound has a decided beneficial effect in bringing out the flavour of the tea. As will be shown later, the consensus of opinion of the tea experts is that the tea treated with No. 2 wash is decidedly of better quality than the untreated or No. 1-wash tea.

Also No. 2 wash possesses a certain " contact " effect, that is to say, any insects on which the wash is sprayed suffer material discomfort, if not death, and the bushes will become uninhabitable to them, because the soda in the solution has a slight burning effect on delicate skinned insects. This explains why Nettle grubs, aphids, and the small tea scale *Chionaspis theæ* were absent from the No. 2 plots.

The Effect of the Washes on the Marketable Product.

After each spraying samples of the treated and untreated teas were submitted for report to fifteen of the senior firms of Tea Brokers in Colombo. There are 552 reports. As previously stated, the tea experts were not notified as to which samples were treated until their reports had been received. In the total number of reports 12 indicated a taint in the tea treated with No. 1 wash, and 12 a taint in that treated with No. 2 wash, and in 27 instances the untreated tea is reported as " peculiar," " smoky," " tarry," " lacks flavour," " thin green cup." 104 times has the tea treated with No. 2 wash been the best, with good quality, fine flavour, and stand out cup ; 84 times No. 1 has been the best ; and 47 times the untreated has been the best ; while in 290 instances the samples were not separately reported upon as to relative quality.

A close analysis of these reports show that No. 2 wash gives the preferable tea, and it materially improves the sample by bringing out the flavour.

Sixteen samples of treated and untreated tea were submitted to the Acting Government Agricultural Chemist, and the following is his report:—

Lead in Sprayed Teas.

"This subject has been thoroughly investigated, and it is considered that no lead passes into the infusion of sprayed teas.

"If minute traces should be present, they are too minute to effect the health of the consumer, especially when the teas are generally blended before consumption."

The first spraying was made the day after plucking, so that eleven days elapsed before the flush was gathered. It was noted that during this period the flush could grow free from Chromate, and it became obvious that any larvæ that might drop from their harbourage in the manurial trees would be able to feed upon the Chromate-free flush. It was, therefore, the object of the Investigation to bring spraying as close as possible to plucking in order that the flush might be sprayed.

The second spraying was advanced to plucking by two days; the third by seven days. Three times spraying was kept midway to plucking, then suddenly jumped to within two days of plucking, and on the next occasion thrown back midway to plucking again. This was done in order that, should there be any likelihood of tainting the sample with the strength of solution used, the taint would be in evidence in the experts' reports, and easily comparable with the reports of the midway treatment. When the flush was plucked, when it was withered and when it was rolled, it was yellow with Chromate. The following are the reports of the experts on the tea made from flush sprayed two days before plucking, and the reports of tea made from flush sprayed six days before plucking:—

[For Reports see next page.]

The evidence from these reports shows that the bushes may be sprayed at any time irrespective of plucking, because the washes have no deleterious effect on the made tea.

THE APPLICATION OF THE WASHES.

The washes were applied to the bushes by means of two Knapsack spraying machines. During the first half of the experiments the machines used were the Assam Pneumatic Knapsack Sprayer, a 2-gallon machine; and the Holder Harriden Pneumatic Knapsack Sprayer, a 4-gallon machine, with a convenient working capacity of 3 gallons; both sprayers are procurable from Messrs. Shaw, Wallace & Co., Calcutta, and cost complete, with fittings and nozzles: Assam, Rs. 65; Holder Harriden, Rs. 115. Both machines gave good service,

Names of Firms.	Reports of Experts on Tea sprayed Two Days before Plucking.			Reports of Experts on Tea sprayed Six Days before Plucking.		
	No. 1 Wash.	No. 2 Wash.	Controls.	No. 1 Wash.	No. 2 Wash.	Controls.
Bartlett & Co.	First: Free from taint	Second: Free from taint	Third: Free from taint	No taint. Thin, light quality	No taint. Thin, light quality	No taint. Slightly "tarry"
Colombo Commercial Co., Ltd.	Third: No taint	Second: No taint	First: No taint	Best	Nearly equal	Worst
Dodwell & Co., Ltd.	First: Increased sediment	Second: Increased sediment	Third: Increased sediment	Second best	Best	Poorest
Forbes & Walker	Quite pure	Quite pure	Rather peculiar	Pure. No taint	Pure. No taint	Slightly tainted
R. Gordon & Co.	Report not received.*			Equal to No. 3 (No. 3=Control)	Inferior	Equal to sample 2. (Sample 2=No. 1)
Gow, Somerville & Co.	Second: No taint	Third: No taint	First: No taint	Pure. No taint. Equal to 2	Pure. No taint. Equal to 1	Pure. No taint. Poorest
Harrisons & Crosfield, Ltd.	No taint	First: No taint	No taint	Untainted	Untainted	Untainted
Harrisons & Eastern Export, Ltd.	No taint. Lighter in liquor	Best: No taint	No taint	No taint	No taint	No taint. Preferable to 1 and 2
Heath & Co.	Second	First	Third	Best	Slightly inferior and little taint	Little taint
Henderson & Co.	Best: Full sweet liquor	Second: Full plain liquor	Worst: Full common liquor	Best: Pure flavour. No taint	Second: No taint	Worst: Coarse flavour
E. John & Co.	Second: No taint	First: No taint	Third: No taint	First: No taint	Second: No taint	Third: No taint
Keell & Waldock	No taint	No taint	No taint	Slight taint	Nice quality	Nice quality
Leechman & Co.	Second: Light, fair strength and quality	Worst: Light, fair strength. Slight taint	Best: Light, fair strength and quality	Good. Truest flavour. No taint	Best. "Catchy"† flavour. No taint	Poorest. No taint
Lipton, Ltd.	Second: Pure. A little point	Best: Fair quality and point	Dull. Slightly metallic flavour	Best: Bright	Plain: Fairly bright	Dull: Peculiarity of flavour. Infusion dull
Mackwood & Co.	No taint	No taint	No taint	No taint	No taint	No taint

* This report was not received, because the expert of Messrs. R. Gordon & Co. was away at the time.
† The "catchy" flavour mentioned by Messrs. Leechman & Co. "is much appreciated by some buyers."

but for extensive spraying the Assam did not meet the requirements, being too small in capacity, and too liable to air leak. A second Holder Harriden was used in place of the Assam sprayer during the latter half of the experiments.

The first essential in the application of a wash is the selection of a nozzle for the particular wash. In the case of Lead Chromate as used against Tea Tortrix, the following points aid in the selection of a nozzle :—

(1) Lead Chromate being expensive at the moment, the least possible quantity should be used.
(2) With the difficulties of water transport to be faced in Ceylon, it is necessary to restrict the amount of water per acre to the minimum.
(3) Lead Chromate being a "stomach" wash, the finest film of the solution over the leaves is all that is necessary.

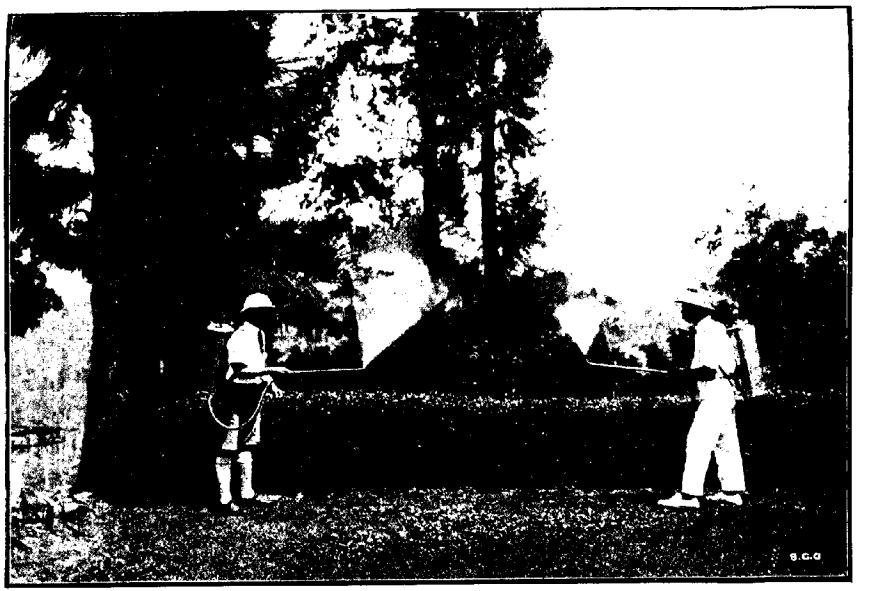
These points indicate that a nozzle giving the most economic delivery of solution is necessary. The plate facing this page shows two types of nozzles in action : 1 is the Holder Harriden, and 2 is the Assam. The latter delivers its capacity of 2 gallons too quickly for an economic delivery. The Holder Harriden delivers a most satisfactory mist, which covers the leaves with a thin film of solution with the least possible waste in the form of drips from leaf to leaf.

The Holder Harriden Pneumatic Knapsack Sprayer can be recommended. The machine weighs but 16 lb. all mounted, and with 3 gallons of solution 46 lb. The pump and piston are small, occupying the minimum of space ; the machine carries a small pressure gauge, a grease cup, and a good strong serviceable bung ; everything is easily and quickly detachable from the container, and the facilities for washing every part are practically perfect. The nozzle has proved economic and perfectly satisfactory. One improvement that should be made to it is to substitute the rubber washer of the nozzle-pin head for a more durable material, because this rubber washer perishes quickly, and spares have not accompanied the machines ordered by the Investigation.

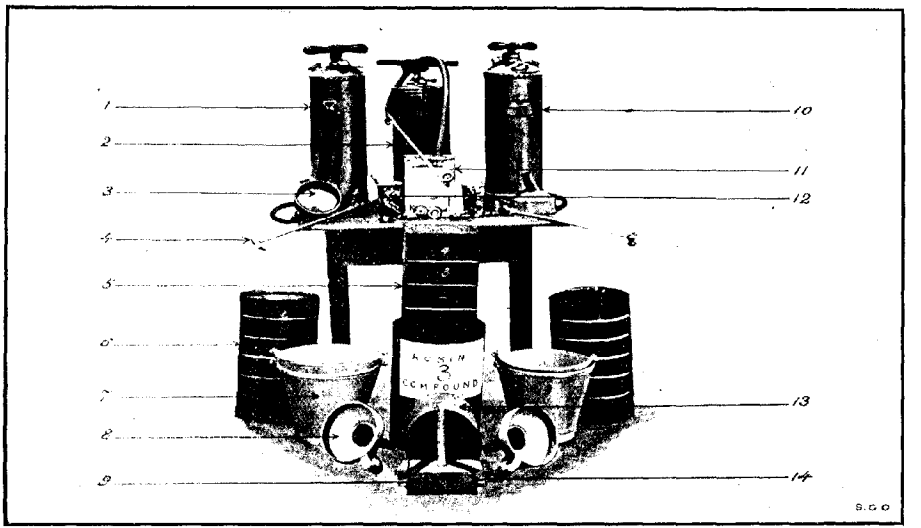
A matter of no little account is that this machine is popular with the cooly ; it is easily handled and worked, about the lightest sprayer of its kind, cleaning is simplicity itself, and it thoroughly stands the hard, and often careless, usage of the cooly.

The apparatus used by the Investigation (see plate facing page 19) consisted of—

Two Holder Harriden machines (1 and 10).
Two mixing tins (12) for mixing Chromate into paste.



1 Jet from the Holder Harriden nozzle. | 2 Jet from the Assam nozzle.



1 Holder Harriden Pneumatic Sprayer (back view).
2 Assam Pneumatic Sprayer.
3 Sieve filter supplied with H. H. machine.
4 Holder Harriden nozzle.
5 4-gallon kerosine tin.
6 6-gallon iron drum.
8 Sieve filters.
9 Plunger mould.
10 H. H. machine (front view).
11 Assam nozzle.
12 *Mixing cups.*
13 [illegible]

Two 6-gallon drums (6) for making up solution on the field ready to spray.

Four buckets (7) for carrying water from reservoir to the 6-gallon drums.

Two sieve-funnels (8) for filling sprayers.

One large sieve (13) for straining water at reservoir to keep back leaves, &c.

One pump-washer mould (9) for making new pump washers when necessary.

One-third of an acre of old full-leafed bushes was sprayed by a single Holder Harriden in six hours; this amounts to 147 bushes per hour, or 47 bushes per 3-gallon fill of the sprayer. When the system of flight breaks is established, the only kind of tea it may be necessary to spray—and it will be not a question of acres, but merely a few bushes here and there—will be young and middle-aged bushes, and these can be sprayed at the rate of 441 bushes just out of pruning per hour, and 196 middle-aged bushes per hour.

Therefore, all the apparatus an estate requires to control Tortrix when flight breaks are established is :—

	Cost, January, 1919. Rs. c.
One Holder Harriden Pneumatic Sprayer, with spare nozzles	130 0
One sieve funnel (supplied with sprayer, No. 3 of plate)	
One mixing tin (a cigarette tin will suffice).	
One 6-gallon drum	7 0
Two buckets	9 0
One pump-washer mould	0 35
One bucket sieve	1 25
	147 60

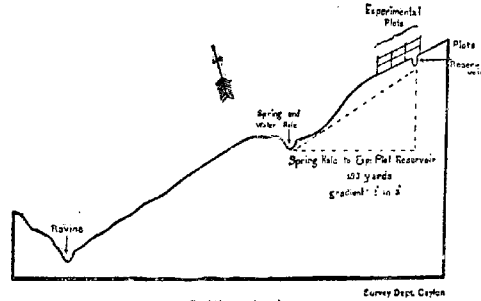
It has been previously stated that the experiments were carried out under estate conditions. Early in the experiments the spraying was done by the Investigator and his assistants, until the coolies had been taught how to mix the solutions, how to pump the machine, how to keep the machine rocking while spraying so as to stir up the contents, and how to spray correctly, then it was merely a matter of supervision on the part of the Investigation. The illustration overleaf shows the process of spraying on the experimental area. One cooly carries the machine, while the other directs the spray, opening up the bushes, and spraying the underside of the leaves. These two coolies take it in turn to carry the sprayer. When more solution must be made, the cooly carrying the machine also directs the spray, while the other mixes and makes up the required amount of wash, thus no time is lost, and the excellent

average of two bushes per minute are sprayed throughout the day. The coolies soon learnt to make up the solutions and spray the bushes correctly. The Chromate is absolutely safe in their hands, and has no effect upon their skins. They must, however, be supervised, for they do not appreciate the necessity of economizing in spray fluid.

Effect of Rain on the Washes.

January to March was a dry period, and no opportunity arose whereby the washes could be tested with regard to rain. In May periodic heavy showers were experienced, but the rain had no effect whatever upon the washes. June produced frequent downpours, and at the moment of spraying; yet it was found that, when the washes had an opportunity of drying on the bushes, rain, no matter how heavy or prolonged, would not wash the solutions off the leaves.

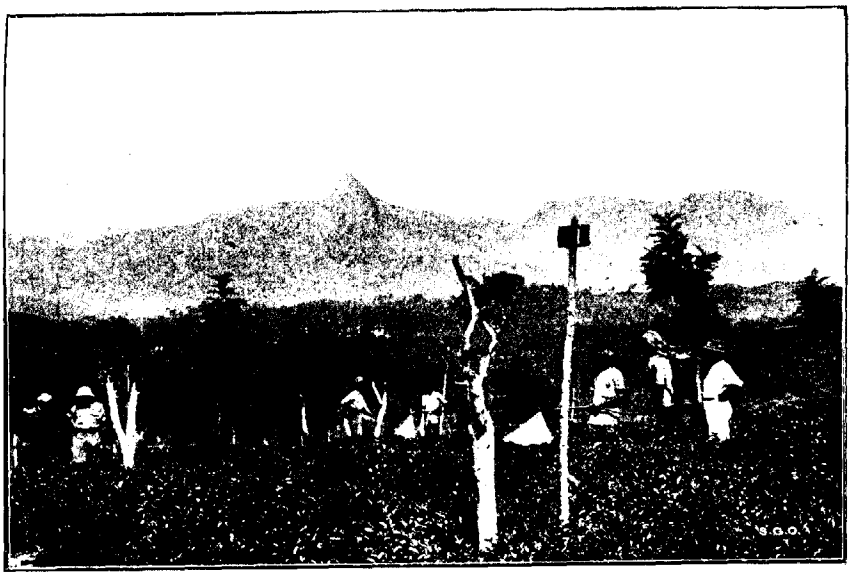
The Investigation hesitates to recommend spraying during the heavy rains, because, though the washes remain unaltered by drizzles, unless they have an opportunity of drying, they will be washed off the leaves by heavy rains; also material discomfort is experienced by those spraying; and, again, when constant and heavy rains are present, the latent polyhedral disease, ever present in the colonies of Tortrix, develops rapidly and kills out an attack by natural means.



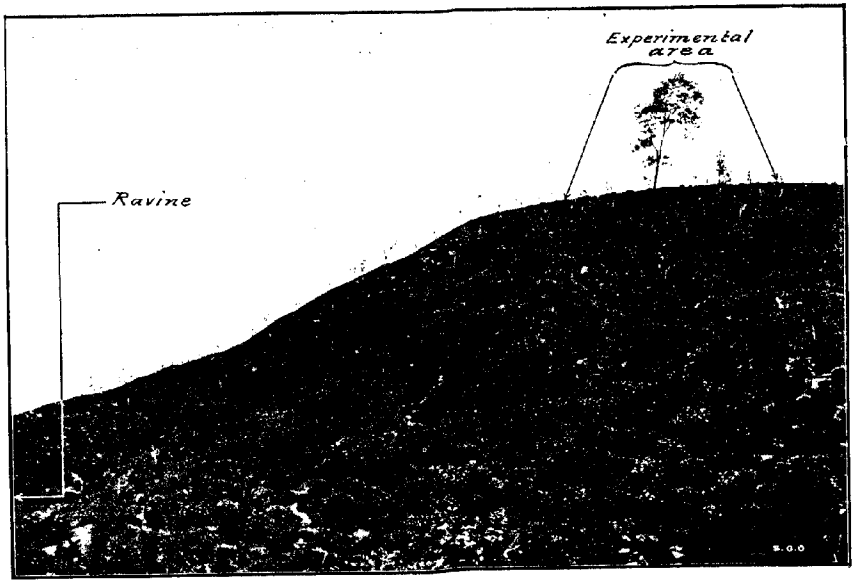
Section: Showing Water System.

Water Transport.

The experimental area being situated on a high bluff, far above a ravine, presented a most difficult problem regarding water transport. The ravine was 390 yards below the experiment plots in a direct line, and the gradient of the land was between one foot in three and one in nine. To carry water



Spraying the Experimental Plots.



Showing contour of land between Ravine and Experimental Area.

It was necessary to tilt the camera face to take the photograph, and this has foreshortened the face of the land to such an extent that the steepness is not shown to effect.

direct from the ravine to the plots would be a most laborious task. The above diagram shows the water difficulty faced by the Investigation, while the opposite plate is a photograph of the actual difficulty. As the face of the camera had to be tilted to take the photograph, the steepness of the land is not shown to effect. The only way to reduce the obstacle to a practical working basis was to dig a small hole, 6 by 4 feet, in the experimental area to act as a reservoir; and at the foot of the one in three gradient, between the ravine and the plots, to dig another small reservoir. The water could then be carried from the ravine to the midway reservoir, and from there to the plots reservoir. Thus could the water be carried in buckets and drums in moderately easy stages to the centre of operation.

The plots reservoir was dug and lined with clay in a half day. In digging the midway reservoir at the foot of the steep gradient, a spring was tapped, which continued to trickle steadily until the hole was filled. This was a lucky accident as far as the water carriers were concerned, but, diminishing the difficulty presented by the water problem, it materially affected the object of the Investigation, namely, to overcome economically the difficulty of water transport. The plots reservoir was easily filled by two coolies in a day from the midway spring water-hole, making the cost of water transport for the first spraying 76 cents.

The plots reservoir had a capacity of some 250 gallons; spraying took but 109 gallons of water, leaving in the reservoir some 142 gallons. During the interval between spraying a certain amount of the water left in the reservoir would evaporate, but while the spring of the midway reservoir functioned, it was never necessary to carry more than 125 gallons of water to the plots reservoir. This was done in half a day by two coolies, making the cost for water transport 38 cents per spraying.

In February the spring of the midway reservoir gave out, and it was necessary to carry water from the ravine to the plots reservoir; this process brought water transport back to the original cost of two coolies carrying all day at 38 cents a day, 76 cents per spraying. The coolies were put on to carrying water the day prior to spraying. The Investigator felt there should be a possibility of reducing even this moderate cost for water transport, and searched the whole land far and near the plots for another source of water. About 350 yards from the plots, in a very slight upward gradient, a mere trickle of water was found in a slight depression of the ground. On a casual observation this source would be condemned as being of no use, but remembering that only 109 gallons of water

were required, and that at intervals of seven to nine to twelve days, there was every possibility that if a hole were dug to receive this trickle, it might accumulate to the required quantity in the time. The hole that was made was not a deep one, but a long shallow trench. From this source sufficient water was gathered to carry on spraying, and the coolies being able to carry drums full of water *downhill* and empty drums uphill, the work of filling the plots reservoir was completed by two coolies in just over quarter of a day, making the cost of water transport 19 cents per spraying.

During the drought great anxiety was felt regarding this source of water ; it became necessary to trace the trickle to its source—a stagnant dampness in an otherwise dry spot—and keep the course free from leaves, twigs, sticks, and anything likely to divert the very valuable flow.

The whole drought was passed at a cost of 19 cents per spraying. When the rains set in, all the sources of water were flowing freely, and occasionally it was unnecessary to carry water to the plots reservoir.

The question of water presented every difficulty, but by establishing a reservoir in the area to be sprayed the difficulties were reduced to a minimum.

Water transport for a moderate scheme of spraying should present no difficulties in the up-country districts. It is easy and possibly profitable to condemn spraying, because the only torrent or waterfall is a mile distant from the area to be sprayed, but torrents and cascades are unnecessary, a mere patch of damp moss may ultimately lend itself to economic benefit.

Summary.

1. In field experimentation with sprays on tea, great care must be taken in interpreting results because of natural variations that occur in the flushing capacity of equal sized plots.
2. Scientific methods may be applied to eliminate these variations, and to determine the significance to be attached to differences in results.
3. The washes used in the experiments have no deleterious effect on the flushing capacity of the bush ; rather do they tend to improve the yield.
4. The washes have no effect upon the sample of made tea.
5. No. 2 wash appears to improve the sample by bringing out the flavour of the tea.
6. No lead passes into the infusion of sprayed teas.
7. The washes are comparatively cheap.
8. The ingredients are easily procurable.

9. The washes are easily manufactured.

10. The ingredients keep in good condition for long periods.

11. They are easily applied, and perfectly safe in the hands of the cooly.

12. Rain has no effect upon the washes once they have dried on the leaves.

13. Difficulties of water transport may be materially lessened by sinking a small reservoir in the area to be treated.

14. With the establishment of a system of flight breaks, the areas of tea ever likely to require spraying are reduced to the minimum.

15. Large quantities of water are not required for spraying with Lead Chromate.

The thanks of the Investigation are due to the Chairman of the Maskeliya Planters' Association, Mr. R. B. Harvey, Mr. L. A. Wright, Mr. J. B. Cotton, Mr. E. M. Mellersh, Mr. J. Dashwood, and Mr. F. A. Bond for much assistance rendered, also to Messrs. Bartleet & Co., Colombo Commercial Co., Ltd., Dodwell & Co., Ltd., Forbes & Walker, R. Gordon & Co., Gow, Somerville & Co., Harrisons & Crosfield, Ltd., Harrisons & Eastern Export, Ltd., Heath & Co., Henderson & Co., E. John & Co., Keell & Waldock, Leechman & Co., Lipton, Ltd., and Mackwood & Co., for testing and reporting on the samples of tea.

NIGEL K. JARDINE,
Entomologist for Tea Tortrix.

Peradeniya, August, 1919.